

# All-For-One, One-For-All

## Advantages of Multi-Axis Machining in Gear Manufacturing

Matthew Jaster, Senior Editor

**The “less is more” mantra is certainly a rallying cry in manufacturing. Technologies like multi-axis machining, 3D printing and automation are enabling companies to be more efficient, cost-conscious and flexible on the shop floor.** These will continue to be trending topics as the metalworking world comes together at IMTS 2016 (September 12-17, Chicago, IL).

“The increasing technological requirements of mechanical parts, combined with a shorter delivery time led us to establish more technology integration on our machines to help our customers to meet these increasing challenges,” said Dr.-Ing. Edmond Bassett, head of technology development at GILDEMEISTER Drehmaschinen GmbH, DMG MORI. Nitin Chaphalkar, product manager at DMG MORI confirms the increasing customer demand of multiple machining operations, such in five-axis Mill-Turn or Turn-Mill machines. “Especially in combination with exclusive technology cycles enabling the shop floor programmer to create complex geometries fast with high process reliability.”

“Today it is not possible to be focused on only one or two technologies. All equipment has to be combined in a suitable way,” said Dr. -Ing. Volker Sellmeier, head of technology development at Index. “Together with classic turning and milling operations, grinding to gear hobbing technologies are needed to machine a part completely in one operation.”

Mike Finn, senior application development engineer at Mazak, stressed the importance of multi-axis flexibility. “If you’re cutting a gear, it’s helpful when you have the ability to perform a variety of operations on a single machine. Turning, milling, power skiving and hobbing, for example, can add new elements to a manufacturer’s gear capabilities and provide additional shop floor

resources. This allows our customers to handle basically any kind of part that comes through the door.”

*Gear Technology* recently spoke with representatives from DMG MORI, Mazak, Index and Breton S.p.A. on the evolution of multi-axis equipment and what to expect from these machines moving forward.

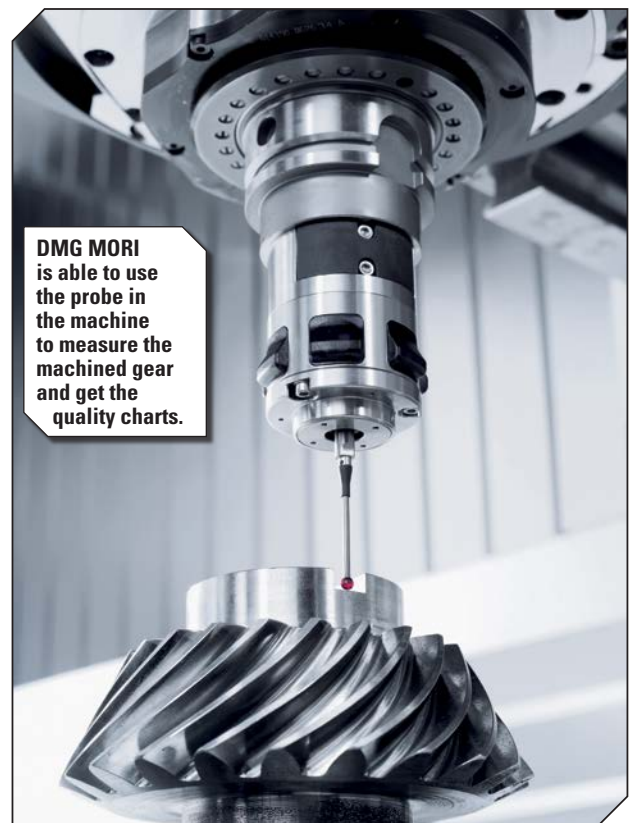
### DMG MORI Highlights Internal Gears, Inspection Technologies

The DMU 125 FD duoBLOCK 4<sup>th</sup> generation is the latest generation of DMU machines. The five-axis milling machine is capable of multiple machining operations including turning, milling and gear machining. “With this latest release, we’ve made some key improvements to machine accuracy and rigidity,” said Chaphalkar. “This machine offers cooling of the entire feed drive which increases the machine accuracy by 30 percent.” Machines in this DMU platform are offered in many different sizes which accept parts from 650 mm (25.59 in.) diameter to 3.4 m (133.85 in.)” he added.

Additionally, DMG MORI has increased the table stiffness which boosts machining performance. “Several DMG MORI exclusive technology cycles are available for use with the machines including *Machine Protection Control (MPC)* and *3D Quickset*,” Chaphalkar said. Today we offer 24 Technology Cycles exclusive to our customers on turning and milling machines. MPC offers protection when

machine vibration reaches a critical limit thanks to automatic fast shut-off, also in case of collisions. Additionally the cutting force can be monitored during drilling and tapping operations. *3D Quickset* is a quick calibration tool that provides accurate assessment of the kinematic center positioning. “Special technology cycles like these keep the machines performing at the highest accuracy level.

While the company will have plenty of innovations to present at IMTS 2016, Chaphalkar discussed two newly developed features that will immensely help gear manufacturers. “One is for machining of internal and external gears. We have been demonstrating the gearSKIVING technology cycle on our machines since last year and now DMG MORI offers a dialog guided programming interface for easy and safe shop floor programming. Customers will be able to



input both tool and gear data to produce a good part with gearSKIVING. This makes it easy for customers to program this complex process.”

This technology is being applied successfully on the DMU 125 FD duoBLOCK, turn-mill machines CTX-TC, and the NTX of DMG MORI.

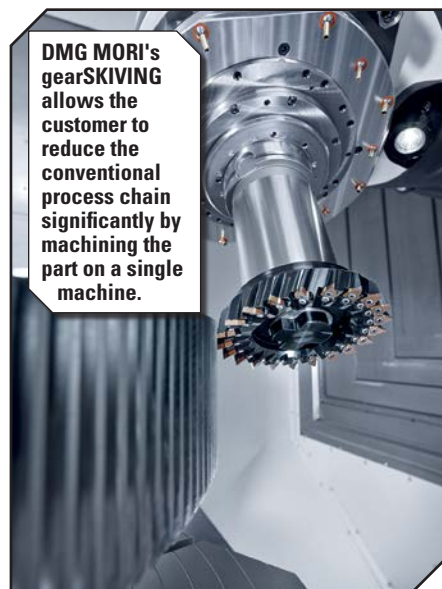
“With gearSKIVING the customer can have the complete machining of the part on only one machine and reduce the conventional process chain significantly. The ability to implement such a complex process demonstrates the machines control capability as well as the rigidity of our machines. We have been able to machine a module 5 internal gear on a 300 mm (11.8 in.) part at quality of DIN 9 (AGMA 2000 – 8) with a cycle time of around 10 minutes,” Chaphalkar said. Smaller modules can be machined with a quality of DIN 7.

Another feature DMG MORI has improved upon is in-process gear inspection. “We are able to use the probe in the machine to measure the machined gear and get the quality charts. We have found good correlation between mea-

surement data from the machine and CMM. This allows the customer to be confident of the machined part before it is removed from the machine. We are able to measure many types of gears including spur, helical and spiral bevel gears. Additionally, this inspection capability gives DMG MORI customers the ability of finish machining heat treated gears. A module in the inspection software is capable of finding the center of the gear, finding the tooth and aligning the part by dividing the stock left for finishing,” he added.

Customers are also very interested in gearSKIVING technologies for machining ID gears. “I believe that is a very efficient process for making smaller module gears and customers would benefit by using this technology,” Chaphalkar said.

Another area the company continues to focus on is CELOS for all new DMG MORI machines. 16 apps help the operator to prepare, optimize and systematically carry out production jobs. CELOS apps provide solution for all applications-making them a solid basis for thoroughly digitized paperless production.



**DMG MORI's gearSKIVING allows the customer to reduce the conventional process chain significantly by machining the part on a single machine.**

“The CELOS environment gives the operator direct access to the machines including optimized planning, clear organization and live monitoring of all production processes. The machine also has about 60 sensors analyzing the processes within the machine tool and delivers detailed information on the current status of machine and the production processes,” Chaphalkar said. “CELOS



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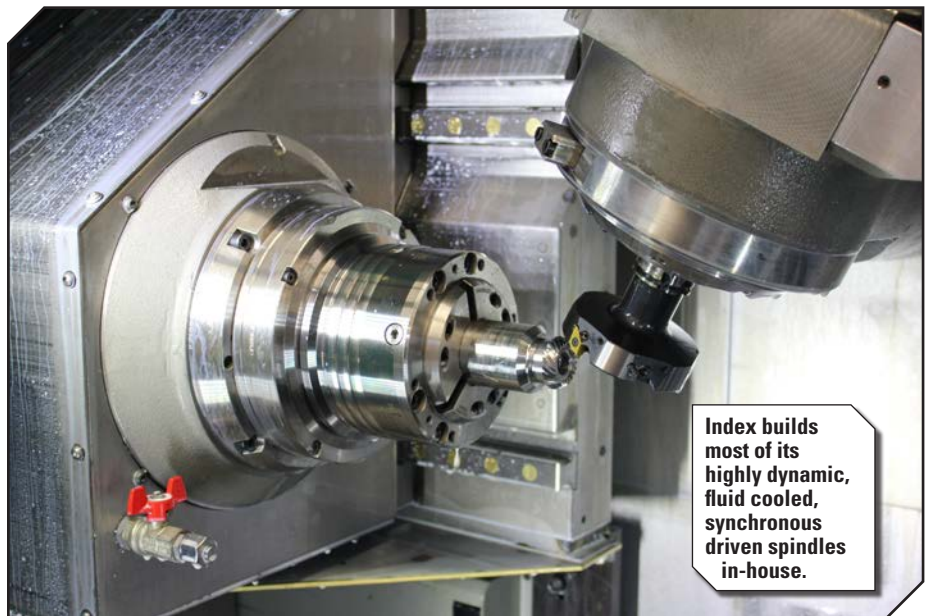
is a key element in a networked intelligent production facility with Industry 4.0. DMG MORI is an active partner in MTConnect standard and all of our machines are compatible for that data exchange format.”

Chaphalkar said that the Industrial Internet of Things (IIoT) and Industry 4.0 are the next developments that DMG MORI is focusing on. “Many machine tools are being underutilized right now and that operational efficiency can be improved,” he added.

### Index Focuses on Complete Machining of Parts

The Index R200 and R300 are two machines gear manufacturers should take particular interest in, according to Sellmeier as well as the Index G220 which will be exhibited at IMTS. “Compared to the R-machines the G220 offers extended possibilities for the machining of shafts by using a tailstock function and/or a steady rest,” Sellmeier said. “Gear hobbing operations of cylindrical gears and spiral bevel gears are also possible on the G220 and quite often needed for the machining of shafts. In addition, the G220 offers the possibility to work with two tools simultaneously on one spindle. The gear hobbing operation of spiral bevel gears on the G220 will be shown at IMTS in Chicago.”

A distinctive feature of Index machine tools is the company’s high in-house production depth. “This means, that almost all of our spindles are built at Index,” Sellmeier added. “We use high-



Index builds most of its highly dynamic, fluid cooled, synchronous driven spindles in-house.

ly dynamic, fluid cooled, synchronous-driven spindles in our machine tools. These spindles feature runouts of less than 1  $\mu\text{m}$ . For most of our spindles it takes approximately only a second to reach the maximum spindle speed.”

Some of the key control advantages include the Siemens control (which is extended by many unique Index features) and offers a high, safe and convenient level of programming. “Together with our *Virtual Machine*, with the *Index VirtualPro* and/or *NXCAM*, our customers are able to program even high quality, complex parts in a short time. Regarding our bevel gear technology, which runs in continuous indexing mode, it is important to have an excellent “electronic axle” to guarantee the absolute synchronization free of play

between the milling spindle and the main spindle. One of our advantages is that our machine tools have no limitation of the maximum spindle speed due to this synchronization,” Sellmeier said.

The company is currently working on the single indexing method where it is necessary to have an extremely precise rotary positioning of the C-axis of the main spindle. “First tests with the single indexing method we did for a customer on a R200 resulted in a total pitch variation less than 3  $\mu\text{m}$ . The high quality of our machine tools makes them very suitable for such challenging gearing operations,” he added.

Index has had several requests for the complete machining of parts from key customers for power tools and gearboxes as well as aerospace customers. “In 2013, we showcased the Index face hobbing technology (continuous indexing method) for the complete machining of spiral bevel gears at the EMO in Hannover for the first time,” Sellmeier said. “Since then we had a lot of requests from customers not only for face hobbing but also for face milling (single indexing method) of spiral bevel gears including cutter tilt and universal motions. At the moment, we are conducting some tests in this direction with our customers.”

Another technology that Index customers are asking for is power skiving. “Many parts could not be machined completely due to some external or internal gear teeth which had to be cut on special shaping machines. Power skiving offers the possibility to cut such



The high quality of Index's R200 makes it suitable for several challenging gear operations.

teeth on the turn-mill center as well. This means less investment, less floor space, faster cycle times and better quality,” Sellmeier said.

Additionally, software development is a key trend facing machine tool providers. “We have to provide all the software which is needed to control not only the machine but also the whole manufacturing process,” Sellmeier said. “Our answer is *Xpanel* which allows the integration of an Index machine in the local network of a customer just like a personal computer. With this solution it is possible for the machine or for the worker to get access to all manufacturing information which is available in the customer’s network.”

While Index is most known for its turning machines, they are focused on the complete machining of parts. “In the future, we plan to extend our capabilities in milling; our new turn-mill center G220 a larger milling spindle with HSK-63 will be released soon. Right now we are also working on the successor of the G200 the G200.2. Other important technologies that we implement on Index machines are grinding and gearing

operations. After the continuous indexing method for spiral bevel gears we plan to release the technology package for the single indexing method including cutter tilt and universal motions towards the end of this year,” Sellmeier said.

Regarding automation, Index has developed a new bar loader, the MBL65, which will be shown at the AMB in Stuttgart this year. “Machine intelligence is a very important topic for us. The cross-linking

of machine tools and production processes will be a key feature for production in the future,” Sellmeier added.

### Mazak Combines Five-Axis Machining with VTC Capabilities

The Mazak Integrex Vertical I and E Series are able to perform milling, turning, boring and drilling operations in a single setup. Manufacturers can reduce the inaccuracies that occur when moving heavy parts across multiple workstations, eliminate work-in-process

inventory and boost overall throughput utilizing these machine tools. “These



Mazak's Integrex Vertical I and E Series are able to perform a variety of tasks for a broad range of application requirements.

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machines meet the changing needs of our gear customers,” Finn said. “They offer two-axis turning, five-axis milling, boring, drilling and other operations via a powerful turning spindle, high-speed milling spindle and a wide array of tool storage options.”

This advanced multitasking functionality allows the machines to easily handle large, highly complex components from aluminum, steel and high-temperature alloy materials. Finn said that the machine’s integral motor C-axes are necessary for speed and accuracy improvements. “There is no gearbox for the milling which allows the table to rotate faster.”

The machine’s direct-drive, large table eliminates backlash for smoother rotation in heavy-duty cutting operations. High-speed and high-torque milling spindle specifications meet a broad range of application requirements in industries such as aerospace, heavy construction and energy. In addition, it comes with a two-pallet changer that provides unattended operations and off-cycle part setup. “This automation capability allows operators to load, unload and inspect parts on one pallet while the machine works on the other undisturbed.”

Mazak’s Mazatrol SmoothX CNC control technology, delivers faster processing of fine-increment programs and higher rotary axis rpms. Faster processing improves fine-increment five-axis tool-path flow used to cut spiral bevel gears and the higher rotary axis rpm allow for optimum cutting conditions for power skiving. “Power skiving has been around for a long time in the gear industry, but it’s still a relatively new concept in the general metalworking world,” Finn said.

There is little room for error in power skiving as both the workpiece and cutter masses spin, the slightest miscalculation in terms of synchronization will immediately cause chatter that will continue until the cutter is completely removed from the cut and adjustments are made. There are also speed limitations. For example, how fast can the C-axis spin while maintaining proper synchronization with the milling spindle? Dedicated skiving machines typically offer higher synchronized-rpm capabilities. Mazak’s SmoothX CNC control technology continues to boost the speeds/rpms at which its multitasking machines maintain skiv-

ing synchronization, according to Finn.

Mazak’s SmoothX CNC control technology functions in high-speed machining, cutter path adjustments, position-controlled hobbing and variable acceleration control. A larger display (19-in.) and intuitive touch screen enables faster programming and user-friendly navigation. Complex gear cutting requires lots of data points. “This is where the SmoothX control really shines,” he added.

In addition to control technology, Mazak has made some general machine design upgrades. The front of the machine, for example, offers a wider work envelope so operators can get in and out of the machine easier. The tool magazine is located next to the operating area for simplified and accessible tool setup.

At IMTS 2016, Mazak plans to roll out a variety of machine tool apps and remote services that will enhance production in the future. “We can’t say much at the moment, but we’re excited about the new machine tool features and capabilities that we’ll be rolling out in Chicago this fall,” Finn said.

### Breton Offers One-Piece Flow Gear Production

Breton offers two specific machine tools relevant to gear manufacturing, the Xceeder series and the Ultrix series. The Ultrix series are multitask five-axis machining centers with a vertical spindle, rotary tilting table, mobile cross-beam, gantry structure and turning bar

for vertical turning independent from the electro-spindle. This range includes various models: Ultrix 800 RT, Ultrix 1000 RT HD and the new for 2016 Ultrix EVO 1200. The table rotates around the C axis and reaches speeds of 100 rpm for milling operations and up to 500 rpm for turning operations. The A tilting axis can reach speeds of 50 rpm. The linear axes travel at speeds of 60 m/min. Ultrix multitask centers offer a number of different machining operations in one including turning, milling, boring and grinding. Downtimes for workpiece repositioning are eliminated. The vertical design of these Breton machining centers is a suitable solution for machining workpieces with diameters greater than the height of the piece.

Xceeder is a range (Xceeder 900 RT, Xceeder 1200 RT HD and the new Xceeder EVO 1400) of high-speed machining centers designed and developed by Breton S.p.A to satisfy demanding machining requirements across various industrial applications such as the aerospace industry, precision engineering and die manufacturing. The gantry structure and rotary tilting worktable with direct drive are significant and innovative features ensuring a high production output and performance enclosed in a compact design. The machine’s steel structure benefits from improved structural rigidity compared to a conventional metal structure thanks to an engineered polymer filler designed to absorb up to 10 times more vibrations



Breton's five-axis machining centers offer flexibility in manufacturing different gear types and sizes.

offering high machining performance when milling complex workpieces with five axes. The thermal symmetry of the machine structure and thermal stabilizing system ensure maximum machining precision when operational and production conditions vary.

“Breton offers a full gear manufacturing software suite with the ability to work both in five-axis with cylindrical end mills and with dedicated face mill tools for small bevel gears,” said Sergio Prior, marketing manager at Breton S.p.A.

The unique characteristics of the Xceeder include four different electrospindles, all with an integral temperature control circuit making it possible to machine special alloys such as titanium and Inconel with the maximum chip removal capacity. All versions of the Xceeder machine line can be equipped with a tool magazine with up to 200 positions, automatic pallet changer and a full range of options that are capable of meeting the most complex requirements.


“The Ultrix EVO 1200 and the Xceeder EVO 1400 are trunnion type mono-block machines that offer a rotating and tilting table where the turn-

ing bar is independent from the electro-spindle,” Prior said. “Multi-touch Breton Gear CAM suite allows operators to modify cutting strategies and tools independently, directly on the machine control, facilitating one-piece flow gear production.”

The flexibility in manufacturing different gear types and sizes is one of the key benefits of the latest Breton machine tool technology. “The ability to make topological modifications to the gear tooth geometry to optimize the contact pattern between two meshing teeth, increase tooth load capabilities and decrease noise are additional benefits,” Prior added.

One customer that is currently utilizing these technologies is SEW Eurodrive. The company is using five-axis milling on case-hardened crown bevel gears (20-in. diameter, AGMA 12). These gears are perfectly meshing with pinions produced on a standard gear cutting machine, according to Prior. “The company is seeing reduced lead times from design to manufacture using only commercial milling tools (round-end mills). This includes any type of spiral bevel,

herringbone, spur, helical, face or special geometry gears up to 40-in.,” Prior said.

The trend today is to optimize the stiffness to mass ratio of the machine structure in order to provide high-speed machining. “Improving dynamic performance by reducing chatter and other vibration phenomenon is essential,” Prior said. “We’re moving more and more towards hybrid machining today by consolidating several machine operations into one machine (turning, milling, threading, etc.).” 

#### For more information:

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